Effect of Porosity On Shear Strength of Fiberglass Composites

Kyle A. Lach

Chemical & Materials Engineering Dept., University of Dayton

Abstract

The presence of porosity is a well known yet difficult to avoid defect in laminated composite materials. Excessive porosity can significantly reduce the mechanical properties of composite structures and is therefore a source of concern. In this study, methods of preparing fiberglass/epoxy composite panels were investigated with the goal of being able to control the amount of porosity in the final panel, e.g. some panels with low porosity, some with high porosity. The panels were then tested for short beam shear strength, which is a property that is typically influenced heavily by interlaminar porosity. Our results indicated that, for the material system tested, the strength values were reduced only when the amount of porosity achieved a very high level (>10%). This implies that a low level of porosity can be tolerated with this material system.

Objectives / Approach

In this study we investigated the effect of porosity on the mechanical properties of fiberglass composites. Panels with varying degrees of porosity were fabricated using hand layup and an autoclave cure cycle at 5 psi, 45 psi, and 85 psi. Porosity was quantified through the use of ultrasonic C-scan nondestructive evaluation and photomicroscopy. The mechanical test used was short beam shear (ASTM D2344).

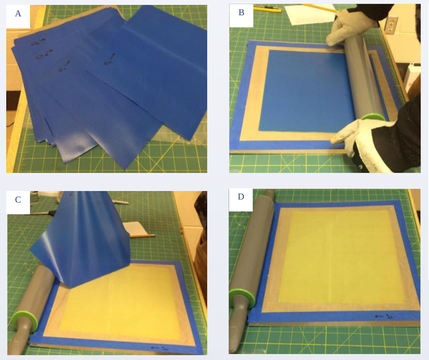
Materials

Table 1. Fiberglass / epoxy prepreg properties (from vendor)

Fiberglass type	E-glass
Fabric Weave Style	7781
Weave Pattern	8HS (8 harness satin)
Yarn Description	Warp: ECDE 75 1/0 Fill: ECDE 75 1/0
Fiber Areal Weight (FAW)	8.71 oz/yd^2 (295 g/m^2)
Fiber Specific Gravity	2.54
Resin content	30 wt%
Resin Specific Gravity	1.21[a], 1.26
Resin T_g (°F/°C)	255 / 124
Prepreg Cured Thickness	0.0089 in (0.226 mm)
Expected Fiber Volume Fraction	0.514

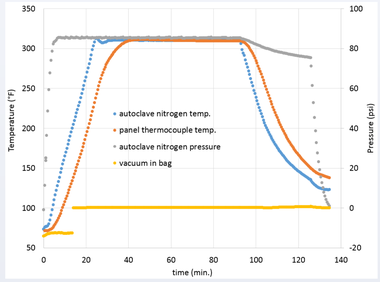
[a] The value of 1.21 was given by the resin manufacturer, but for this study we used an effective value of 1.26 to account for additional densification in a composite environment and with autoclave curing.

Fabrication Method

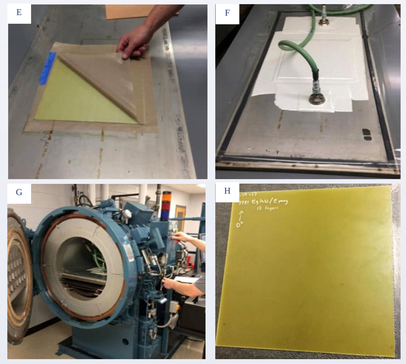


Hand Lay-up Steps

(A) Individual plies were cut to 12 in. x 12 in. dimensions, and the 0° direction was marked
(B) Bottom peel ply (blue material) was removed, and the first layer was placed on a plate and compacted with a rolling pin.
(C) Top peel ply was removed; remaining plies were added and compacted sequentially.
(D) Final layup pre-cure; total of 12 layers.



Autoclave Cure Cycle Details
(Shown for 85psi panel)

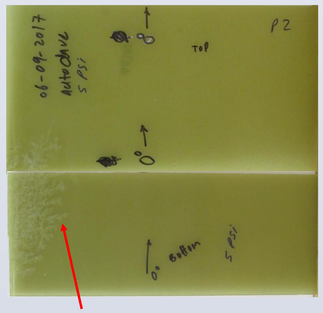


Cure Cycle Steps

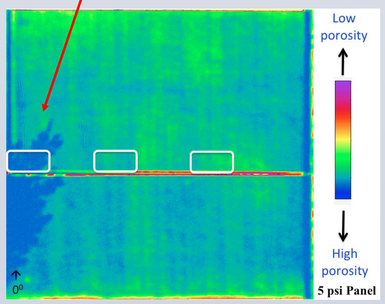
(E) Layup was placed between two non-porous Teflon sheets on a steel tray
(F) Breather ply, vacuum bag, vacuum ports, and sealant were added, and the bag was leak-checked
(G) Vacuum bag setup was placed in the autoclave, and the cure cycle was run (see figure, left)
(H) Final panel after cure cycle and unbagging.

Results and Discussions

Nondestructive Evaluation (NDE)*

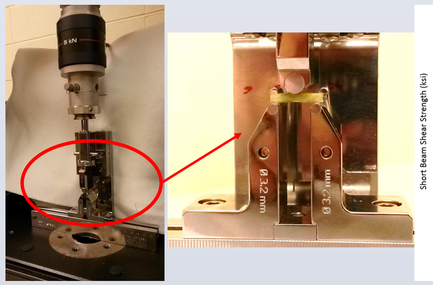


Visually high porosity area at the edge

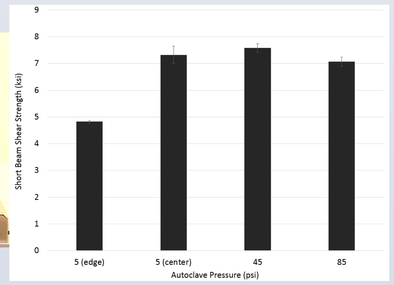


Porosity Evaluation (top) photograph of **5 psi panel** and (bottom) C-scan results for **5 psi panel,** showing high level of porosity. The horizontal line in the middle is an air gap where the two sides of the already-cut panel were butted together for the test.

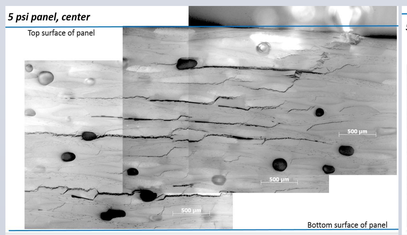
Mechanical Testing (Short Beam Shear)



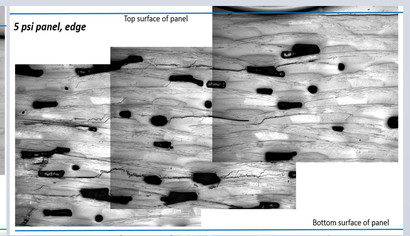
Instron machine and Short Beam Shear (SBS) Fixture



SBS results for fiberglass panels. The error bars represent 95% confidence interval (± 1.96s)



Fracture surface of SBS specimens taken from the center of 5 psi panel. Although there are some large voids, many of the interlaminar cracks do not propagate through these voids



Fracture surface of SBS specimens taken from the edge of 5 psi panel. The voids have a more elongated morphology compared to the voids at the panel center. Most or all of the interlaminar cracks propagate through these voids, leading to lower SBS results

Conclusion

A hand lay-up and autoclave curing procedure was successfully implemented to produce fiberglass/epoxy panels with varying degrees of porosity. The differences in porosity were achieved by varying the pressure during the autoclave cure cycle. Although the C-scan results show a steady reduction in porosity with increased pressure, the short beam shear testing as well as the optical microscopy indicate that there was a significant change in porosity between the 5 psi and 45 psi cure cycles, while there was only a minor change in porosity between the 45 psi and 85 psi cure cycles. The 5 psi panel contained two distinct areas of high porosity, which showed differences in void morphology. Only the highest level of porosity resulted in a significant reduction in shear strength.

Future Work

1. Check for repeatability of porosity levels in 5 psi, 45 psi, and 85 psi panels
2. Compare porosity levels of additional panels fabricated at intermediate pressures including, but not limited to: 15 psi, 25 psi, 35 psi
3. Investigate effects of using different fabric styles, such as a plain weave

Faculty Advisors/Collaborators

Donald Klosterman, Ph.D.
Chemical & Materials Engineering Dept.
University of Dayton

Charles Browning, Ph.D.
Chemical & Materials Engineering Dept.
University of Dayton

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*C-scan results by Dr. Ray Ko, University of Dayton Research Institute (UDRI)